



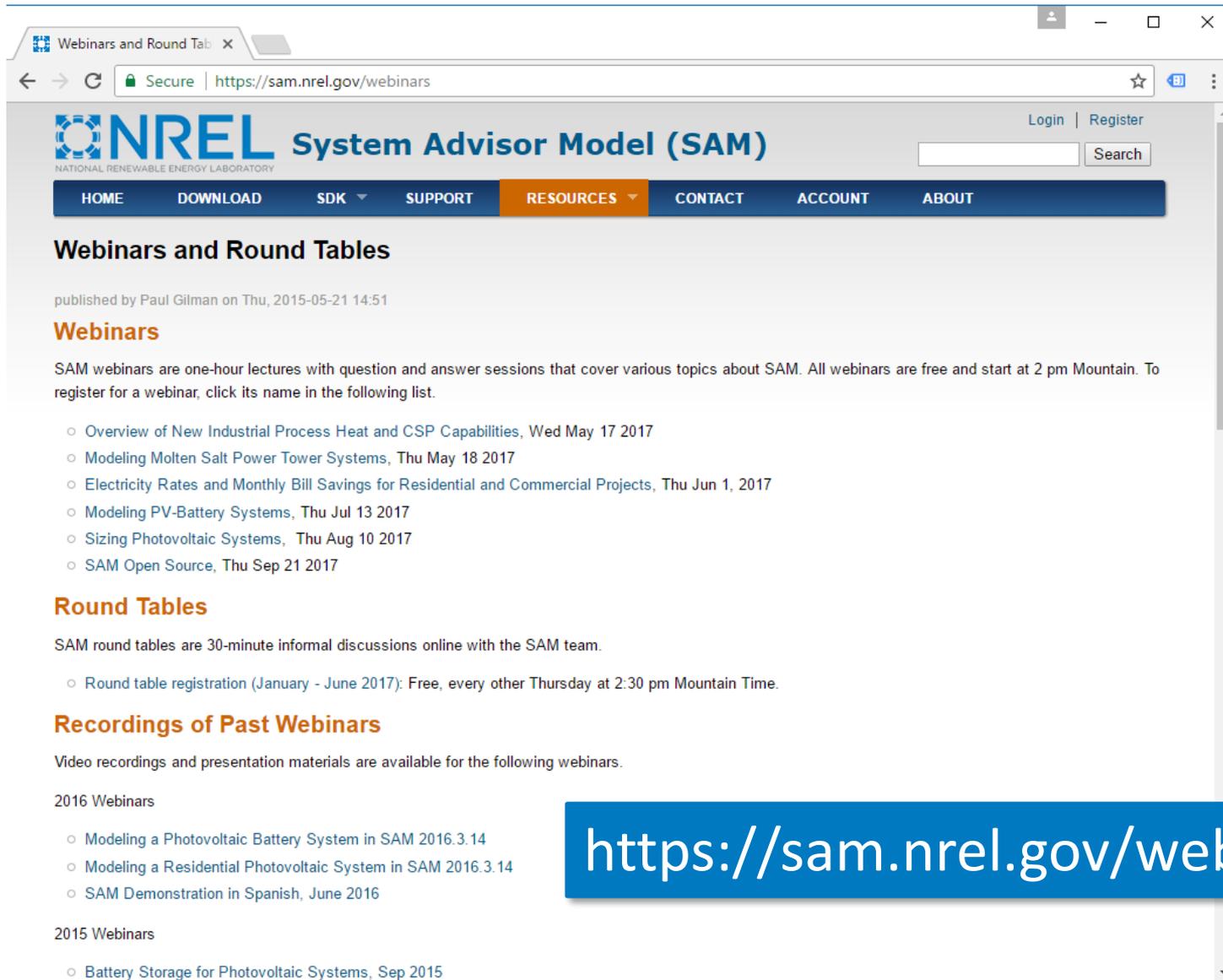
SAM Webinars 2017: Modeling Photovoltaic-Battery Systems in SAM 2017.1.17

Nicholas DiOrio

July 13, 2017

- Overview of New Industrial Process Heat and CSP Capabilities, May 17
- Modeling Molten Salt Power Tower Systems, May 18
- Electricity Rates and Monthly Bill Savings for Residential and Commercial Projects, June 1
- **Modeling PV-Battery Systems, July 13**
- Sizing Photovoltaic Systems, August 10
- SAM Open Source, September 21

Registration Links and Webinar Recordings



The screenshot shows a web browser window with the URL <https://sam.nrel.gov/webinars>. The page header includes the NREL logo and the text "System Advisor Model (SAM)". A navigation menu contains links for HOME, DOWNLOAD, SDK, SUPPORT, RESOURCES, CONTACT, ACCOUNT, and ABOUT. The main content area is titled "Webinars and Round Tables" and includes a sub-section for "Webinars" with a list of upcoming events, a "Round Tables" section, and a "Recordings of Past Webinars" section.

Webinars and Round Tables

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Webinars

SAM webinars are one-hour lectures with question and answer sessions that cover various topics about SAM. All webinars are free and start at 2 pm Mountain. To register for a webinar, click its name in the following list.

- Overview of New Industrial Process Heat and CSP Capabilities, Wed May 17 2017
- Modeling Molten Salt Power Tower Systems, Thu May 18 2017
- Electricity Rates and Monthly Bill Savings for Residential and Commercial Projects, Thu Jun 1, 2017
- Modeling PV-Battery Systems, Thu Jul 13 2017
- Sizing Photovoltaic Systems, Thu Aug 10 2017
- SAM Open Source, Thu Sep 21 2017

Round Tables

SAM round tables are 30-minute informal discussions online with the SAM team.

- Round table registration (January - June 2017): Free, every other Thursday at 2:30 pm Mountain Time.

Recordings of Past Webinars

Video recordings and presentation materials are available for the following webinars.

2016 Webinars

- Modeling a Photovoltaic Battery System in SAM 2016.3.14
- Modeling a Residential Photovoltaic System in SAM 2016.3.14
- SAM Demonstration in Spanish, June 2016

2015 Webinars

- Battery Storage for Photovoltaic Systems, Sep 2015

<https://sam.nrel.gov/webinars>

Outline

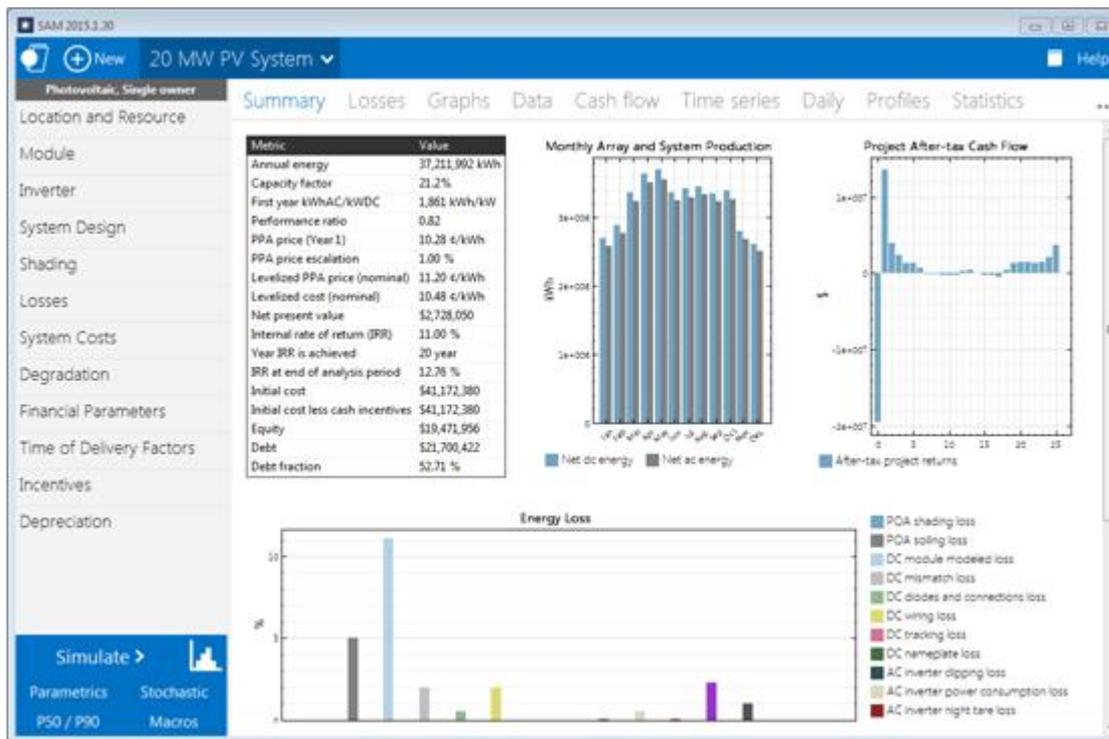
- Overview of SAM's PV-Battery model
- New features
 - DC Connected batteries
 - Utility-scale PV-battery systems
 - Simple battery model for PVWatts
 - Automated dispatch improvements
- Demo
- Q&A

System Advisor Model (SAM)

SAM is free software for modeling the performance and economics of renewable energy projects.

<http://sam.nrel.gov>

- Developed by NREL with funding from DOE
- Windows, OSX, and Linux
- One or two new versions per year
- Software Development Kit (SDK)
- Support
 - Help system
 - Documents on website
 - Online forum
 - Contact form on website



SAM is planned to be released as an open-source project in the next few weeks!

PV System Modeling in SAM

The screenshot shows the SAM 2016.3.14 interface. On the left, a tree view shows the 'Photovoltaic, Commercial' category selected. The main window is titled 'Example PV System' and has several sections:

- Download a weather file from the NREL NSRDB:** Includes a 'Download...' button and a link to 'NSRDB Map'.
- Choose a weather file from the solar resource library:** Contains a search box and a table of weather files.
- Annual Weather Data Summary:** Displays key metrics for the selected location.
- Use a specific weather file on disk:** Includes a 'Browse...' button for local files.

The table in the 'Choose a weather file from the solar resource library' section is as follows:

Name	Station ID	Latitude	Longitude	Time zone	Elevation
USA AZ Grand Canyon Natl P (TMY3)	723783	35.95	-112.15	-7	2065
USA AZ Kingman (amos) (TMY3)	723700	35.267	-113.95	-7	1033
USA AZ Luke Afb (TMY3)	722785	33.55	-112.367	-7	331
USA AZ Page Muni (amos) (TMY3)	723710	36.933	-111.45	-7	1304
USA AZ Phoenix (TMY2)	23183	33.4333	-112.017	-7	339
USA AZ Phoenix Sky Harbor Intl Ap (TMY3)	722790	33.45	-111.982	-7	337

The 'Annual Weather Data Summary' shows:

- Global horizontal: 5.80 kWh/m²/day
- Direct normal (beam): 6.90 kWh/m²/day
- Diffuse horizontal: 1.55 kWh/m²/day
- Average temperature: 22.5 °C
- Average wind speed: 3.0 m/s
- Maximum snow depth: 0 cm

At the bottom, the 'Simulate' button is highlighted with a green arrow, and a green circular arrow indicates a refresh or update action.

Key inputs:

Solar resource data:

NSRDB (via 'Download' button), TMY2, TMY3

PV modules:

Simple efficiency, Single-diode, or Sandia models

System design:

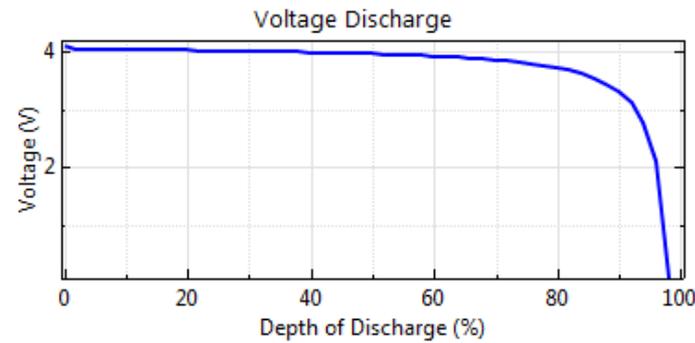
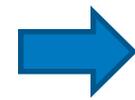
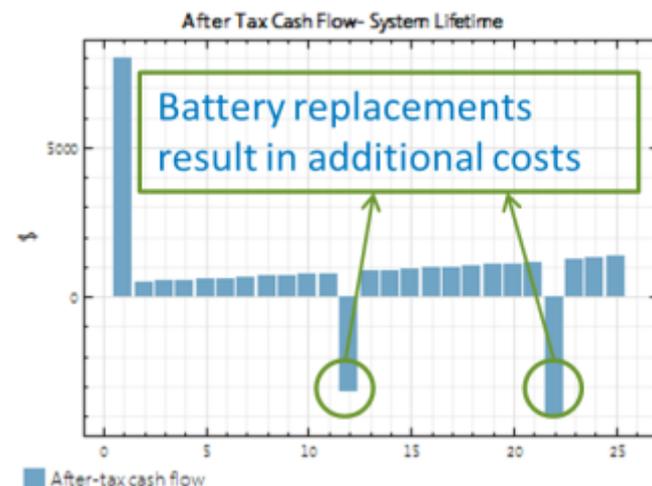
Configure system size, type, and orientation

Single-year vs lifetime:

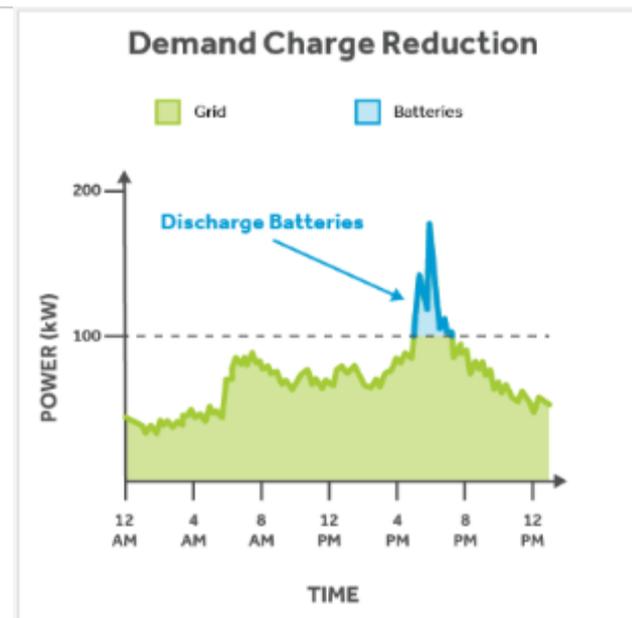
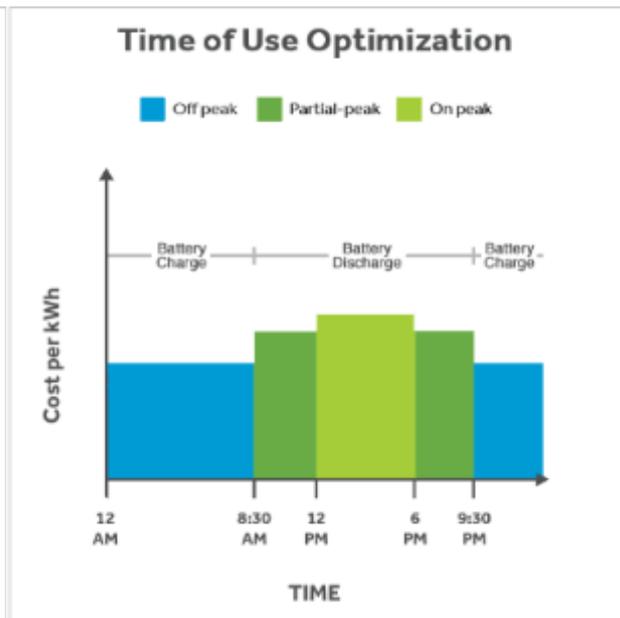
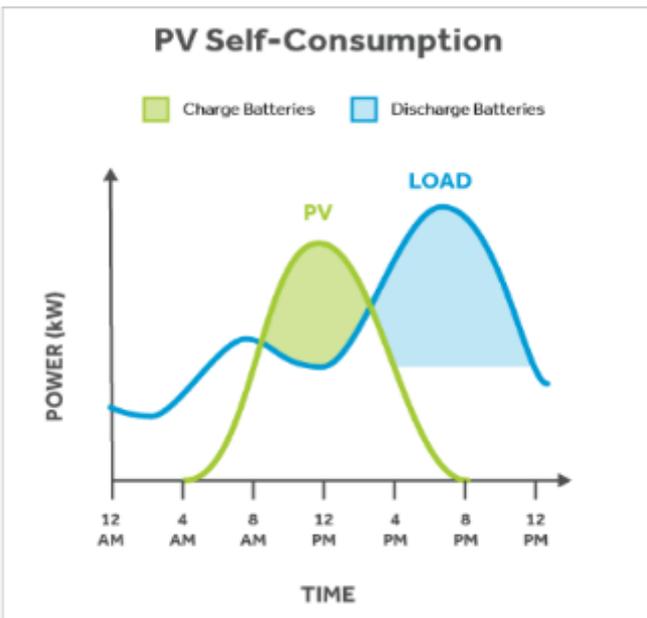
Select lifetime mode to run full model in all years

Battery Model Overview

- Techno-economic model for behind-the-meter and front-of-meter scenarios.
 - Lead acid & lithium ion battery chemistries
 - System lifetime analysis including battery replacement costs
 - Models for terminal voltage, capacity, temperature
 - Multiple dispatch controllers available



Behind-the-meter storage



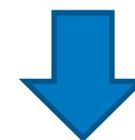
Images from: <http://www.aquionenergy.com/>



- Batteries charged primarily from PV eligible for Federal ITC subject to 75% cliff
- End of NEM in some states



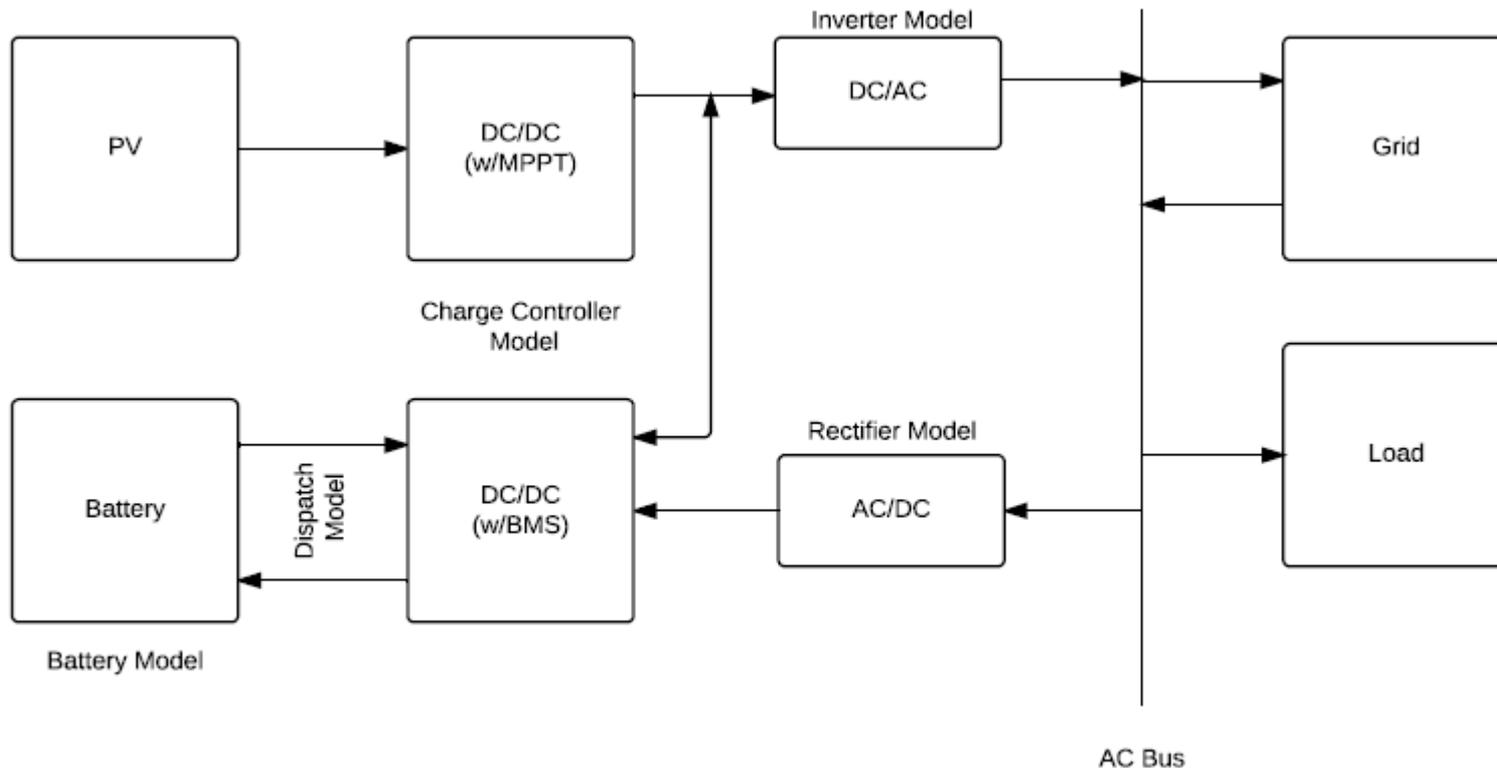
- Residential and commercial utility rate structures with high TOU charges.
- Charge when rate is low, discharge when rate is high



- Commercial utility structures can have very high TOU demand charges.

DC Connected Battery

Configuration Options: DC Connected battery



- Previously, only an AC-connected battery was possible in SAM
- The DC-connected option models single point conversion losses in:
 - The PV DC power optimizer (DC/DC w/MPPT)
 - The DC/DC BMS
- Combined battery and PV DC power go through a common inverter

DC Connected battery potential pitfalls

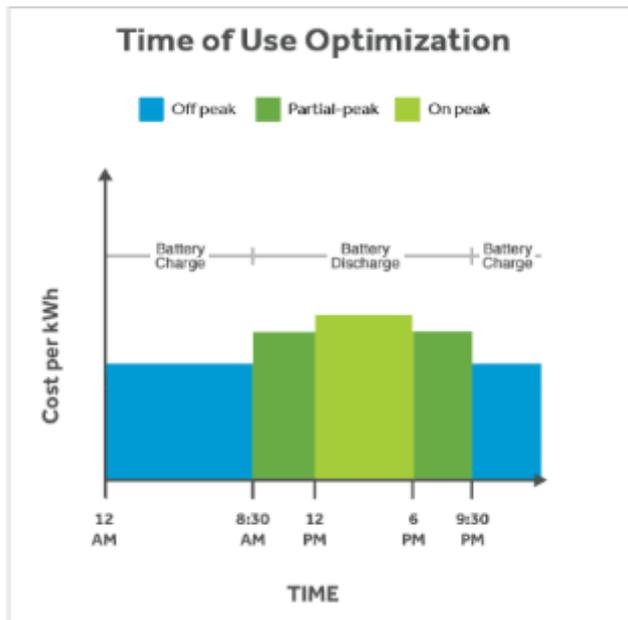
The screenshot shows the SAM 2017.1.17 software interface. The left sidebar contains navigation options: Location and Resource, Module, Inverter, System Design, Shading and Snow, Losses, Lifetime, Battery Storage, System Costs, and Financial Parameters. The main window is titled 'System Sizing' and has two radio buttons: 'Specify desired array size' (unselected) and 'Specify modules and inverters' (selected). Under 'Specify desired array size', there are input fields for 'Desired array size' (4 kWdc) and 'DC to AC ratio' (1.20). Under 'Specify modules and inverters', there are input fields for 'Modules per string' (7), 'Strings in parallel' (2), and 'Number of inverters' (1). Below this is the 'Configuration at Reference Conditions' section, which is divided into 'Modules' and 'Inverters' columns. The 'Modules' column includes: Nameplate capacity (4.693 kWdc), Number of modules (14), Modules per string (7), Strings in parallel (2), Total module area (22.8 m²), String Voc (475.3 V), and String Vmp (401.1 V). The 'Inverters' column includes: Total capacity (3.800 kWac), Total capacity (3.928 kWdc), Number of inverters (1), Maximum DC voltage (600.0 Vdc), Minimum MPPT voltage (250.0 Vdc), Maximum MPPT voltage (480.0 Vdc), and Battery maximum power (6.503 kWdc). A red-bordered box highlights a 'Sizing messages (see Help for details):' text box containing the text: 'DC to AC ratio of PV only is 1.23. Actual DC to AC ratio with DC-connected battery (common inverter) is 2.95.' Below this box is a note: 'Voltage and capacity ratings are at module reference conditions shown on the Module page.'

Modules		Inverters	
Nameplate capacity	4.693 kWdc	Total capacity	3.800 kWac
Number of modules	14	Total capacity	3.928 kWdc
Modules per string	7	Number of inverters	1
Strings in parallel	2	Maximum DC voltage	600.0 Vdc
Total module area	22.8 m ²	Minimum MPPT voltage	250.0 Vdc
String Voc	475.3 V	Maximum MPPT voltage	480.0 Vdc
String Vmp	401.1 V	Battery maximum power	6.503 kWdc

- The DC to AC ratio of the PV system does not account for the DC-connected battery.
- If you undersize the inverter, discharging the battery during peak PV production will result in inverter clipping.

Utility-scale (PPA) battery systems

Front-of-the-meter storage



Images from: <http://www.aquionenergy.com/>



- PPA time-of-use optimization for changing PPA sell rates.
- Charge from PV when rate is low, discharge when rate is high

* SAM 2017.1.17

Choose a performance model, and then choose from the available financial models.

Photovoltaic (detailed)	Residential (distributed)
Photovoltaic (PVWatts)	Commercial (distributed)
High concentration PV	Third party ownership
Wind	PPA single owner (utility)
Biomass combustion	PPA partnership flip with debt (utility)
Geothermal	PPA partnership flip without debt (utility)
Solar water heating	PPA sale leaseback (utility)
Generic system	LCOE calculator (FCR method)
CSP parabolic trough (physical)	No financial model



- In SAM, multiple PPA models available

PVWatts Battery Model

PVWatts Battery

SAM 2017.1.17: CAUsers\ndiorio\Documents\Projects\nickdiorio\battery\presentations\2017_07_13_Webinar\Webinar_demo.sam

File ▾ (+) Add DC-connected battery ▾ PPA Battery ▾ PVWatts Battery ▾

PVWatts, Commercial

Location and Resource

System Design

System Costs

Lifetime

Financial Parameters

Incentives

Electricity Rates

Electric Load

System Parameters

System nameplate size: 199.752 kWdc

Module type: Standard ▾

DC to AC ratio: 1.2

Rated inverter size: 166.46 kWac

Inverter efficiency: 96 %

Orientation

Array type: Fixed open rack ▾

Tilt: 20 degrees

Azimuth: 180 degrees

Ground coverage ratio: 0.4

Losses

Soiling	2 %	Connections	0.5 %
Shading	3 %	Light-induced degradation	1.5 %
Snow	0 %	Nameplate	1 %
Mismatch	2 %	Age	0 %
Wiring	2 %	Availability	3 %

User-specified total system losses: 20.95 %

Total system losses: 14.08 %

-Shading-

Edit shading losses Edit shading... Open 3D shade calculator...

-Curtailment and Availability-

Curtailment and availability losses reduce the system output to represent system outages or other events.

Edit losses... Constant loss: 0.0 %
Hourly losses: None
Custom periods: None

Battery Bank

Enable battery

Battery capacity: 100 kWh

Battery power: 30 kW

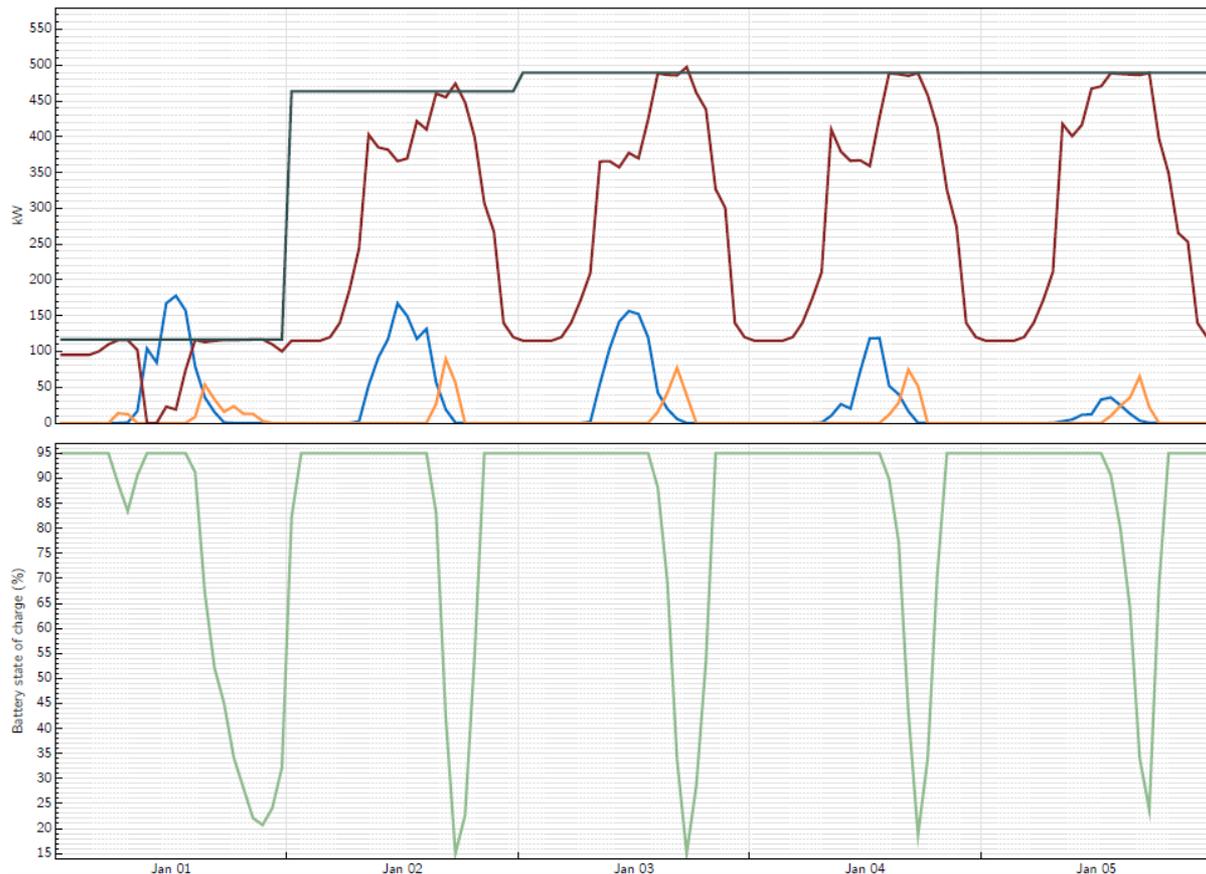
Battery chemistry: Lithium Ion ▾

Battery dispatch: Peak Shaving (look ahead) ▾

- Four inputs
 - Battery capacity and power
 - Battery chemistry
 - Battery dispatch (only offers automated controllers).
- Suitable only for high-level studies of demand charge reduction

Automated dispatch improvements

Enter custom demand target



- Hourly Data: Electricity to load from PV (kW)
- Hourly Data: Electricity to load from battery (kW)
- Hourly Data: Electricity to load from grid (kW)
- Hourly Data: Electricity grid power target for automated battery dispatch (kW)
- Hourly Data: Battery state of charge (%)

- User can specify the allowed amount of grid power purchased at every time step.
- The battery control will then either charge or discharge the battery to seek to match that target.
- Offers detailed way for users to customize dispatch on time-step basis.

Thank you!

www.nrel.gov



Configuration options: AC Connected battery

